User experience evaluation of intelligent sports bracelet based on multi-factor fusion

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Abstract: In order to overcome the problems of the traditional methods, such as the low accuracy of calculating the weight of evaluation factors, the high error rate of evaluation and the long output time of evaluation results, a user experience evaluation method based on multi-factor fusion was proposed. Building intelligent motion bracelet user experience evaluation system, determine various evaluation factors relative to the membership degree of evaluation factor set, to construct judgment matrix, get the weights of preliminary results, the weighting results are consistency check, get the final weight calculation results, and the multi-factor fusion method was used to construct intelligent motion bracelet user experience evaluation model, get the final user experience evaluation result. Experimental results show that the calculation accuracy of the weight of evaluation factors is more than 94%, the error rate of evaluation varies from 0 to 2%, and the average output time of evaluation results is 0.62 s.

Keywords: multi-factor fusion; intelligent sports bracelet; user experience evaluation; evaluation factor set; weighting.

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1 Introduction

In recent years, with the rapid development of information technology, various types of digital products have gradually increased, and gradually penetrated into all aspects of people's work and life. Especially with the continuous improvement of people's attention to health, there are more and more kinds of wearable intelligent devices, among which intelligent sports bracelet is one (Lao et al., 2021). After wearing the intelligent sports bracelet, the user can connect with other smart devices through Bluetooth, which can synchronise the data of the user's exercise, diet and sleep to the smart device, and use the data to provide the user with quality health guidance. But with the development of science and technology and the progress of the society, the development of intelligent motion hand ring has been in trouble, especially in the current intelligent motion bracelet as the low degree of innovation, the R&D function set is not reasonable and it remains to be development of a variety of problems, such as performance, so we need to evaluate the intelligent motion bracelet user experience, according to the user experience evaluation results to improve the performance of intelligent motion bracelet, make better use of intelligent user bracelet to understand their motion law, so for the intelligent motion bracelet user experience evaluation method research has important research significance (Zhong, 2018; Huang et al., 2020).

Current research on intelligent sports bracelet user experience evaluation is relatively small. For example, Zhang et al. (2018) proposed a user experience evaluation method for intelligent sports bracelet based on questionnaire survey, this method is mainly by questionnaire survey and literature analysis method, on the basis of analysis to the brand, visual design, interactive feedback and so on six intelligent motion bracelet user experience evaluation index, and dimension of each index was calculated on the basis of the preliminary build intelligent motion bracelet user experience evaluation model, and use the parameter optimisation method to optimise the evaluation model, get the final intelligent motion bracelet user experience evaluation results. However, this method has the problem of low evaluation error rate, which is far from the ideal application effect. Cao and Zhang (2018) proposed a user experience evaluation method based on factor analysis and comprehensive fuzzy method. This method is used to study as the important foundation, building intelligent motion bracelet user behaviour model, in order to get more the important factors that affect the user experience, and by using factor analysis method to obtain more than one common factor, which experience, security protection, fluency experience, experience to function indexes, constructing evaluation index system of the user experience, on this basis, using the user experience on the method of synthetic fuzzy evaluation, but the evaluation result output time is too long, the actual application effect is not good. Li et al. (2017) proposed a user experience evaluation method based on fuzzy comprehensive evaluation method, with senses, interaction, brand and technology as the important thoughts, build user experience multi-index evaluation model, in order to determine the multiple evaluation indexes weight and membership degree, on the basis of the fuzzy comprehensive evaluation method to obtain the final user experience evaluation results, but this method is low weight calculation accuracy evaluation factors and evaluate the problem of high error rate, the actual application effect is not good.

Due to the above method in the design process by considering the factors of less, leading to the evaluation factors weight calculation accuracy of these methods is low output, high error rate, and the results of assessment time is long, resulting in a decline in intelligent motion bracelet user experience evaluation performance, in order to solve the problems of these methods, so this paper introduced the factors integration of ideas, a new user experience evaluation method for intelligent sports bracelet is designed. The overall design scheme of the method is as follows:

1 The user experience evaluation system of intelligent sports bracelet was established to obtain the evaluation factor set and determine the membership degree of each evaluation factor relative to the evaluation factor set.

2 Based on the membership degree calculation results, the relative importance between the two evaluation elements is compared, and the judgment matrix of the upper element relative to the lower element is constructed to obtain the preliminary weight calculation results, and the consistency test of the weight calculation results is carried out to obtain the final weight calculation results. A user experience evaluation model of intelligent sports bracelet was constructed by multi-factor fusion method. The weight judgment result was taken as the input of the model, and the final user experience evaluation result was taken as the output of the model, so as to realise user experience evaluation.

3 Compare the calculation accuracy, evaluation error rate and output time of evaluation results of different methods for user experience evaluation of intelligent sports bracelets.

2 Design of user experience evaluation method for intelligent sports bracelet

2.1 Construction of user experience evaluation system for intelligent sports bracelet

Building intelligent motion bracelet before user experience evaluation system, it is necessary to study a large number of research materials, this article with the literature data method, questionnaire investigation and expert inquiry method as the foundation, uses the qualitative and quantitative evaluation index, a combination of design has the characteristics of comprehensiveness, effectiveness and accuracy of Ouyang et al. (2017), in order to build up the evaluation system has more reliability and scientific, therefore to build intelligent motion bracelet user experience evaluation system need to follow the principles of scientific, integrity principle, operational principle and structure principle (Ren et al., 2017; Jiang et al., 2018).

According to the above analysis, multiple user experience factors of intelligent sports bracelets were obtained and each index in the user experience evaluation system of intelligent sports bracelets was coded (Wei et al., 2018), among which the first-level index was $A_i\left(i=1,2,\ldots,n\right)$, the second-level index was $B_i\left(i=1,2,\ldots,n\right)$, and the third-level index was $C_i\left(i=1,2,\ldots,n\right)$. The specific user experience evaluation system of intelligent sports bracelet is shown in Table 1.

Table 1 User experience evaluation system of intelligent sports bracelet

First level indicators	*Secondary level indicators*	*Third level indicators*
Appearance perception	Shape attractiveness	Single fixation time
		Compare fixation time
		First look probability
	Rationality of layout	Key position
		Key size
		SIM card loading method
	Hand comfort	Texture of material
		Size
		Modelling
Operational availability	Easy to learn and easy to use	Task time
		Error rate
		Efficiency
Comprehensive satisfaction	Interestingness	Enjoyment
		Interesting
	Impressionism	Friendliness
		Impression
	Purchasability	Desire to buy
		Recommendation

Based on the user experience evaluation system of intelligent sports bracelet, the user experience evaluation factor set of intelligent sports bracelet is obtained, and the membership degree of each factor relative to the evaluation factor set is obtained by using fuzzy set theory. According to the analysis of fuzzy set theory, in general, the value range of membership function of fuzzy set is [0, 1], which is significantly different from the value range of classical set {0, 1}, so the membership degree calculated by fuzzy set theory is more accurate. Generally, fuzzy sets think that an element belongs to the characteristic function of a certain set, and its membership value is not only 1 or 0, but can take any value between [0, 1]. Therefore, the relationship between elements and sets changes from absolute belonging in classical set theory to relative belonging, so the results are more comprehensive, and can more truly reflect the relationship between elements and sets membership relations between sets (Guo et al., 2018; Yang and Yuan, 2018).

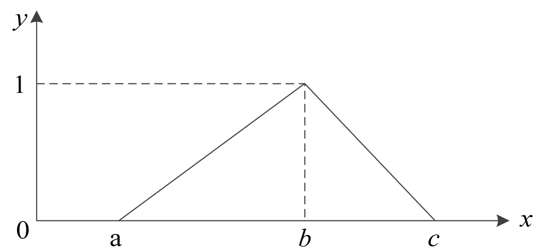
Hypothesis $U=\{u_1,u_2,\ldots,u_n\}$ represents the user experience evaluation factor set of intelligent sports bracelet, and the following relationship exists:

$$\tilde{A}:U\rightarrow[0,1],x\rightarrow\mu_{\tilde{A}}(x) \tag{1}$$

In the above formula, $\tilde{A}$ represents the fuzzy set of user experience evaluation of intelligent sports bracelet, and $\mu_{\tilde{A}}(x)$ represents that element x belongs to the membership function of $\tilde{A}$ (Long, 2019).

In this paper, by comparing various commonly used membership functions and the overall characteristics of the user experience evaluation factor set of the intelligent sports bracelet in this paper, the triangular function is taken as its membership function, as shown in Figure 1.

Figure 1 Triangle function



In this paper, the membership degree of the user experience evaluation factors of each intelligent sports bracelet relative to the evaluation factor set is calculated by the following function. The specific description of this function is as follows:

$$f(x,a,b,c)=\begin{cases} 1, x=b \\ \dfrac{x-a}{b-a}, a\le x<b \\ \dfrac{c-x}{c-b}, b\le x<c \\ 0, else \end{cases} \tag{2}$$

In the above formula, x,a,b,c respectively represents different evaluation factors.

In summary, through the establishment of user experience evaluation system of intelligent sports bracelet, the evaluation factor set of user experience of intelligent sports bracelet is obtained, and the membership degree of each evaluation factor relative to the evaluation factor set is determined, which lays a solid foundation for the subsequent evaluation results.

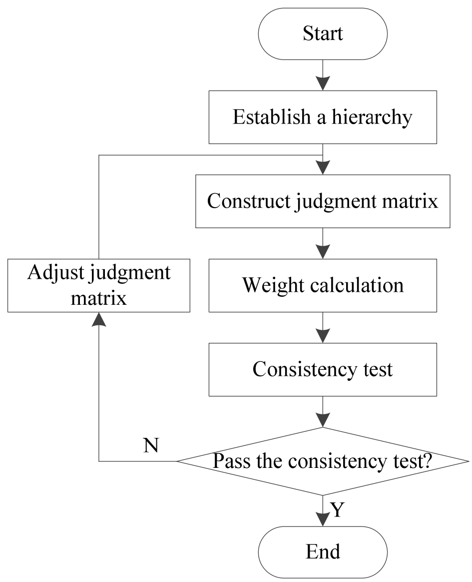
2.2 User experience evaluation of intelligent sports bracelet based on multi-factor fusion

Due to the few factors considered by the traditional method in the design process, the performance of user experience evaluation of intelligent sports bracelet is reduced. Therefore, in order to solve the problems existing in the traditional method, this paper introduces the multi-factor fusion method and designs a new user experience evaluation method of intelligent sports bracelet. Multifactor fusion method refers to the fusion of multiple evaluation factors in the evaluation process, make the evaluation results can be more fully reflect the actual situation, the method of multi-factor fusion applied to intelligent motion bracelet on the evaluation of the user experience, can make the method has high evaluation factor weight calculation accuracy, low error rate and low output takes the characteristics of the evaluation results, In this way, user experience evaluation effect of intelligent sports bracelet can be improved.

In this paper, using the analytic hierarchy process (AHP) to determine the various intelligent motion bracelet user experience weights of evaluation factors, this method is a kind of combining qualitative and quantitative method of a kind of method, also is a kind of multi-objective decision method, can make intelligent motion bracelet user experience quantitative evaluation factors, and provide important basis for relevant quantitative research (Xu and Bao, 2018; Yao and Xu, 2018).

The general analytic hierarchy process is shown in Figure 2.

Figure 2 A general analytic hierarchy process



Analysis Figure 2, the hierarchical analysis to an orderly have ladder hierarchy structure of evaluation as the foundation, in order to define the proportion of different evaluation factors scale, on the basis of the comparison between the relative importance of the two elements in the structure, and build the upper element relative to the lower level elements of judgement matrix, finally obtain each element relative to the relative importance of the upper elements, and the weighting results are consistency check, get the final judgment result.

Since the evaluation factor set is $U = \{u_1, u_2, \ldots, u_n\}$, u_{ij} is used to represent the relative importance of u_i to u_j on this basis, and u_{ij} value is described by 1–9 scale method, as shown in Table 2.

Pair comparison of user experience evaluation factors of intelligent sports bracelets in *U* is made according to Table 2. In this process, a judgment matrix is needed to be constructed (Xia et al., 2017; Zhu et al., 2017), which is described as follows:

$$P = \begin{bmatrix} u_{11} & \cdots & u_{1n} \\ \vdots & \ddots & \vdots \\ u_{1n} & \cdots & u_{un} \end{bmatrix} \tag{3}$$

Table 2 Relationship between scale and importance level

Scale u_{ij}	*Importance level*
1	u_i has the same importance as u_j
3	u_i is slightly more important than u_j
5	u_i is significantly more important than u_j
7	u_i strong is more important than u_j
9	u_i extremes are more important than u_j
2, 4, 6, 8	In between two adjacent scales, take the average value
Reverse $1/m$, where m represents the scale value	u_i versus u_j, the importance of u_j over u_i is expressed by $u_{ij} = 1/u_{ij}$

In general, the relationship between the elements in judgment matrix P is shown as follows.

$$u_{11} = u_{22} = \ldots = u_{nn} = 1 \tag{4}$$

$$u_{ij} = \frac{1}{u_{ij}} \tag{5}$$

In the above formula, $i, j = 1, 2, \ldots, n$, it is assumed that there is a random number k. If the following formula is true, P is the consistency judgment matrix:

$$u_{ij} = u_{ki} * u_{kj} \tag{6}$$

Assuming that the number of evaluation factors for user experience of intelligent sports bracelet is n, the number of experts participating in weight evaluation of evaluation factors is s, and the judgment matrix of i-th experts is set as B_i, then the ranking vector of evaluation factors can be obtained by using the expert judgment matrix as follows:

$$U_i = \left(U_{i1}, U_{i2}, \ldots, U_{in}\right)^T \tag{7}$$

In the above formula, $i = 1, 2, \ldots, n$.

On this basis, the included angle cosine formula is adopted to measure the similarity between individual U_i and U_j in user experience evaluation factors of intelligent sports bracelet (Fan, 2020; Li et al., 2018), and the specific measurement formula is as follows:

$$c(i, j) = \frac{\sum_{k=1}^{n} u_{ki} * u_{kj}}{\left[\left(\sum_{k=1}^{n} u_{ki}^2\right) * \left(\sum_{k=1}^{n} u_{kj}^2\right)\right]^{1/2}} \tag{8}$$

The closer the value of $c(i, j)$ is to 1, the higher the similarity degree of ranking vectors of different individuals is. On this basis, the ranking vector of individual experts is divided into different categories by using the idea of cluster analysis. The number of categories is mainly represented by t. If h_p is set as the number of individual ranking vector of p-th class (Guo et al., 2018), then the confidence factor of individual ranking vector can be calculated by using h_p, and the specific formula is as follows:

$$T_i = \frac{h_p}{t} \tag{9}$$

When the confidence factors of individual ordering vectors are the same, it means that the vector belongs to the same category, so the corresponding weight calculation results are similar, which is taken as the basis for determining the weight coefficient. The specific calculation formula is as follows:

$$F_i = \frac{h_p}{\sum_{q=1}^{t} h_q^2} \tag{10}$$

According to the weight coefficient calculation results, the experts' evaluation normalisation matrix *V* for each evaluation factor is calculated. Then, the weight calculation results of user experience evaluation factors of intelligent sports bracelet are as follows:

$$W_i = \sum_{i=1}^{n} U_i * V_i \tag{11}$$

AHP is used to determine the intelligent motion bracelet user experience evaluation factors in the process of weight coefficient, the problem can be converted to ask *P* characteristic vector and the largest eigenvalue problem, so the characteristic vector calculation result is the weight coefficient of all the evaluation factors, and test the accuracy of the weight coefficient of the standard is consistency check. The calculation formula of consistency index is described as follows:

$$CI = \frac{\lambda_{\max} - N}{N} - 1 \tag{12}$$

In the above formula, $\lambda_{\max}$ represents the maximum eigenvalue of the judgment matrix, and *N* represents the order of the judgment matrix.

Due to the similarity of some judgment matrices in practice, it is necessary to set an average random consistency index, which can be expressed by *RI*. The specific value range of *RI* is shown in Table 3.

Table 3 *RI* value range

Order *N*	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Among them, the calculation formula of random consistency ratio is shown as follows.

$$CR = \frac{CI}{RI} \tag{13}$$

When $CR < 0.1$, judgment matrix *P* has a satisfactory consistency, and the weight coefficient does not meet the above relation, then *P* needs to be adjusted continuously until it meets the relevant requirements, which indicates that the weight calculation results pass the consistency test.

In order to avoid large differences in the weight calculation results of user experience evaluation factors for multiple intelligent sports bracelets, the linear mean normalisation method was adopted in this paper to process the weight calculation results. The specific normalisation formula is as follows:

In order to avoid large differences in the weight calculation results of user experience evaluation factors for multiple intelligent sports bracelets, the linear mean normalisation method was adopted in this paper to process the weight calculation results. The specific normalisation formula is as follows:

$$f\left(z\right)=\frac{Bz}{\overline{z}} \tag{14}$$

In the above formula, z represents the weight variable to be normalised, B represents the adjustment coefficient, and $\overline{z}$ represents the average value of the weight vector. The calculation formula of this value is as follows:

$$\overline{z}=\frac{1}{n}\sum_{i=1}^{n}z\left(i\right) \tag{15}$$

In the above formula, $z(i)$ represents the weight of the i-th evaluation factors.

The normalisation processing results of user experience evaluation factors for intelligent sports bracelets are described as follows:

$$W_i^{'}=\frac{W_i}{\sum_{i=1}^{n}W_i} \tag{16}$$

The weight of user experience evaluation factors of intelligent sports bracelet is weighted and summed, and the result is the average relative importance of evaluation factors. The calculation formula is as follows:

$$a_i^{sun}=\sum_{i=1}^{n}W_i^{'}\times a_i^k \tag{17}$$

In the above formula, a_i^k represents the weighting coefficient.

According to the weight calculation results of user experience evaluation factors for intelligent sports bracelets, a user experience evaluation model was established by multi-factor fusion method. The description of the model is as follows:

$$R=DI_i\times DH_i\left(i=1,2,\ldots,N\right) \tag{18}$$

In the above formula, I_i represents the final calculation result of the weight of the i-th evaluation factor, H_i represents the grading result of user experience, and D represents the function evaluation coefficient in the user experience process of intelligent sports bracelet.

To sum up, this paper mainly through the establishment of intelligent motion bracelet user experience evaluation system, evaluation factors were obtained, and to determine the membership degree of evaluation factors relative to the evaluation factors set, and calculate the weights of evaluation factors, multiple factors fusion method was used to construct intelligent motion bracelet user experience evaluation model, get the final evaluation result of the user experience.

3 Experimental design and result analysis

3.1 Overall experimental scheme

In order to test the practical application effect of the user experience evaluation method of intelligent sports bracelet based on multi-factor fusion proposed in this paper, an experimental test is required, as shown in the overall experimental scheme below.

1. *Experimental environment*: In order to ensure the scientific nature and reliability of the experimental results, the experiments should be carried out in the same experimental environment. The specific experimental environment is shown in Table 4.
2. *Experimental data*: The experimental data are from the R&D departments of large intelligent sports bracelet manufacturers. On this basis, all product parameters are integrated and statistically processed, and the final processed data are taken as experimental sample data, in order to improve the accuracy of the simulation experiment.
3. The Zhang et al. (2018) method, Cao and Zhang (2018) method, Li et al. (2017) method and the method in this paper were taken as the experimental comparison method to test the practical application effect of different methods.
4. The calculation accuracy, evaluation error and output time of evaluation results of user experience evaluation factors of intelligent sports bracelet were taken as important evaluation indexes. Among them, the more accurate the weight calculation of user experience evaluation factors of intelligent sports bracelet is, the more accurate the weight calculation result is. The user experience evaluation error of intelligent sports bracelet refers to the ratio of the difference between the evaluation result and the actual result and the actual result. The lower the error rate, the higher the evaluation accuracy. The output time of user experience evaluation result of intelligent sports bracelet refers to the time taken to get the evaluation result of user experience of intelligent sports bracelet. The shorter the output time of the result, the higher the evaluation efficiency.

Table 4 Simulation experiment environment

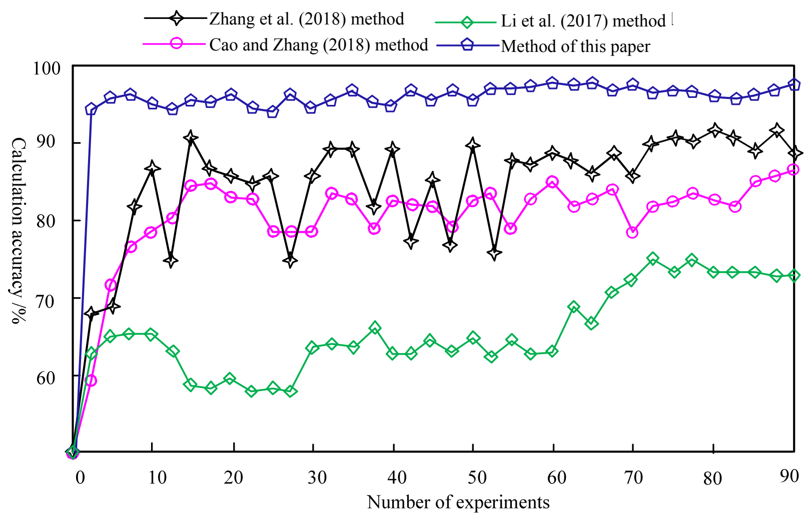
Runtime environment	*Configuration*	*Parameter*
Hardware environment	CPU	Intel(R)Core(TM)i5-9400
	Frequency	2.90GHz
	RAM	16.0GB
Software environment	Operating system	Windows 10
	Version	18362.1082 pro
	Digits	64bit
	Analog software language	APDL
	Simulation software	Matlab 7.0

3.2 Analysis of experimental results

3.2.1 Comparison of accuracy of weight calculation of evaluation factors

According to the above experimental design, the calculation accuracy of weight of user experience evaluation factors of intelligent sports bracelet was firstly compared with the Zhang et al. (2018) method, Cao and Zhang (2018) method, Li et al. (2017) method and the method of this paper. The results are shown in Figure 3.

Figure 3 Comparison results of accuracy of weight calculation of evaluation factors

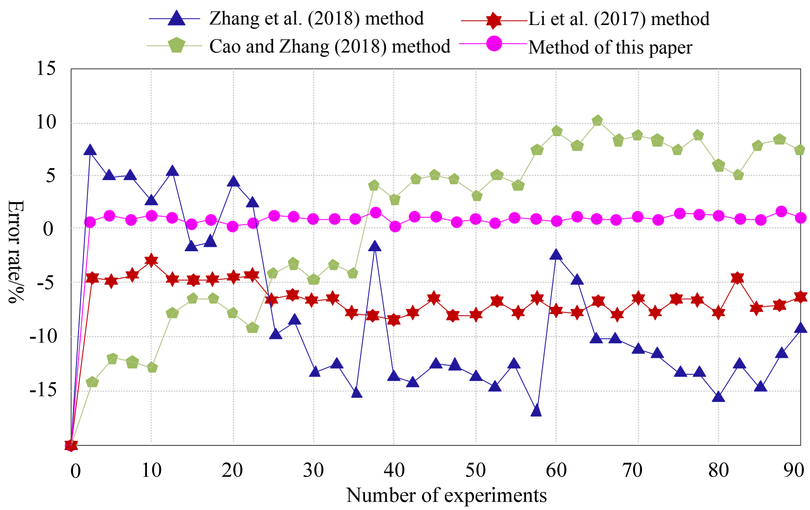


Analysing Figure 3, the Zhang et al. (2018) method the evaluation factors weight calculation accuracy range is 78–91%, the Cao and Zhang (2018) method the evaluation factors weight calculation accuracy range is 58–86%, refer to the Li et al. (2017) method the evaluation factors weight calculation accuracy range is 57–74%, the method of weighting accuracy evaluation factors remain above 94%, illustrate the method of intelligent motion bracelet user experience evaluation factor weight calculation accuracy is better, the reason is that the method is mainly based on the membership degree calculation, compare the relative importance between the two elements of evaluation, and build the upper element relative to the lower level elements of judgement matrix, obtain the weight of preliminary results, and the weighting results are consistency check, the final weight calculation result is obtained, so it has a higher accuracy of the weight calculation of evaluation factors, which can lay a solid foundation for the subsequent evaluation results.

3.2.2 Comparison of evaluation error rates

In order to further compare the comprehensive performance of different methods, the error rate of user experience evaluation of intelligent sports bracelet was compared, and the results are shown in Figure 4.

Figure 4 Comparison results of evaluation error rate



Analysing Figure 4 data shows that in Zhang et al. (2018) method of evaluation error rate between –17% and 7% of change, of Cao and Zhang (2018) method to evaluate error rate between –14% and 11% change, refer to the method of Li et al. (2017) evaluation error rate change between –4% and 8%, and the method of evaluation error rate between 0~2%, the lowest evaluation error rate in the four methods, and the shows that using this method can realise precise intelligent motion bracelet user experience evaluation, the reason is that the method in intelligent motion bracelet user experience evaluation factor weight calculation results, the multi-factor fusion method was used to construct intelligent motion bracelet user experience evaluation model, get the final user experience evaluation results, and therefore has a lower error rate of evaluation.

3.2.3 Comparison of output time of evaluation results

Finally, the output time of user experience evaluation results of the Zhang et al. (2018) method, Cao and Zhang (2018) method, Li et al. (2017) method and the method of this paper were compared, and the results are shown in Table 5.

Referenced by the data in Table 5 shows that the method of Zhang et al. (2018) the evaluation results of the output time average of 4.52 s, method of Cao and Zhang (2018) the evaluation results of the output time average of 1.75 s, refer to the method of Li et al. (2017) the evaluation results of the output time average of 5.10 s, is that the four kinds of methods of the evaluation results output for the longest, and compared with these methods, the method of evaluation result output time average of 0.62 s, is that the four kinds of methods of evaluation result output the shortest time, indicated that the method of evaluation is more efficient, able to quickly implement intelligent motion bracelet evaluation of user experience. The reason is that this method adopts multi-factor fusion method to build user experience evaluation model of intelligent sports bracelet, so as to get user experience evaluation results quickly.

Table 5 Output time of evaluation results

Number of experiment	Output time of evaluation results/s			
	Zhang et al. (2018) method	Cao and Zhang (2018) method	Li et al. (2017) method	Method of this paper
10	3.45	1.25	4.36	0.58
20	4.52	1.63	4.87	0.62
30	2.35	1.98	4.63	0.84
40	4.84	1.87	5.84	0.45
50	5.21	1.58	4.96	0.56
60	6.32	2.01	4.88	0.47
70	5.47	2.22	5.14	0.65
80	3.65	1.54	5.85	0.64
90	4.87	1.63	5.36	0.78
Average value	4.52	1.75	5.10	0.62

To sum up, the method of evaluation factor weight calculation accuracy always stay above 94%, evaluate error rate between 0~2% change, evaluation result output time average of 0.62s, to illustrate the evaluation factors weight calculation accuracy of the method and the user experience evaluation accuracy is high, and the evaluation efficiency is low, can further promote in practice.

4 Conclusion

1. In order to improve the performance of the intelligent sports bracelet, it is necessary to evaluate the user experience of the intelligent sports bracelet, in order to adjust the functions of the intelligent sports bracelet according to user opinions. Therefore, this paper proposes a user experience evaluation method of the intelligent sports bracelet based on multi-factor fusion.
2. Mainly through the establishment of intelligent motion bracelet user experience evaluation system, evaluation factors were obtained, and determine the various evaluation factors relative to the evaluation factor set membership degree, and calculate the weights of evaluation factors, multiple factors fusion method was used to construct intelligent motion bracelet user experience evaluation model, get the final evaluation result of the user experience.
3. The experimental results show that the calculation accuracy of evaluation factor weight of the method in this paper is always above 94%, and the calculation accuracy of index weight is higher. The evaluation error rate varies from 0 to 2%, and the evaluation accuracy is higher. The average output time of the evaluation results is 0.62 s. The evaluation time is shorter and the efficiency is higher, so it can be widely used in practice.

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